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Research Article

Effect of vacuum cooling on physico-chemical properties of organic coriander

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Abstract

The aim of this study was to find out optimum cooling process parameters and effects of vacuum cooling on physico-chemical properties of organic cilantro or coriander. The effect of vacuum pressure reserving operation mode on cooling time, weight loss percentage and temperature variation of organic cilantro were investigated. Vacuum cooling process of organic cilantro packed in 18 hole polyethylene bags using different vacuum pressure reserving operation modes were experimented with. The holding pressures for vacuum-cooled organic cilantro packed in holed polyethylene bags were set at two different levels, namely at 6 and 7 millibars. The pressures were experimented with at 3 levels of reserving time of 1, 2 and 3 minutes. The weight loss percentage during pre-cooling to the temperature of 5±1°C using reserving pressure of 6 milibars for 1, 2, and 3 minutes were 0.67, 0.81 and 1.33%, respectively. For the weight loss percentage during preooling using reserving pressure of 7 milibars for 1, 2, and 3 minutes were 0.98, 1.61 and 2.18%, respectively. The optimum condition for vacuum cooling process of organic cilantro at the initial temperature of 22-26°C was attributed to the final pressure of 6 milibars, with reserving time of 2 minutes. After vacuum cooling, organic cilantro was then stored at 5±1°C for physico-chemical property analysis. The results showed that vacuum cooling had no effect on the loss of fresh weight, change of colour, total soluble solids and chlorophyll, but had a significant effect on amount of vitamin C and shelf life. However, it was found that pre-cooling was an important factor in maintaining longer shelf life. The end of shelf life was determined by more than 5% of yellowing area on the leaves and more than 10% of wilting and rot. The appearance of pre-cooled organic cilantro was better than non pre-cooled samples. Vacuum cooling has proved to be the fastest and steadiest method of cooling. Through the vacuum cooling process, organic cilantro cooled down quickly. This research also exemplified that organic cilantro pre-cooled to 5- °C and stored at 5±1- °C were significantly better preserved with longer shelf life of about 7 days, compared to the normal storage time of 3 days.

Keywords: vacuum cooling, organic cilantro, polyethylene bag, shelf life**,** pre-cooling *Coriandrum sativum* Linn., Thailand.

Introduction

Cilantro, or coriander, (*Coriandrum sativum* Linn.) belongs to the family Umbelliferae with botanical classification: Division Angiospermae, Class Dicotyledonae, Sub-class Polypetalae, Series Calyciflorae, Order Umbellales, Genus Apiaceae, Species Umbelliferae [1]. Cilantro is an important spice crop and occupies a prime position in flavouring substances. However, cilantro constantly deteriorates in quality throughout their storage life and during transportation. Vacuum cooling technology is a proven technology widely applied on post-processing of harvested agricultural products [2]. Vacuum cooling is achieved through boiling part of the moisture of the product under vacuum conditions. The major characteristic of vacuum cooling is that the product can be cooled at extremely high speed, which is unsurpassed by conventional cooling methods. Traditionally it has been used to remove field heat of leafy vegetables after harvest in order to prolong product shelf-life [3]. The benefits of vacuum cooling have been widely reported [4, 5, 6]. It can cool lettuce from 25°C to 1°C and, if combined with cold storage at 1°C, it can increase the shelf-life of lettuce from 3–5 days at ambient temperature to 14 days [7]. Vacuum cooling process is a new technology therefore the research is limited, especially the research into cilantro. The aim of this study was to find out optimum cooling process parameters and effects of vacuum cooling on physico-chemical properties of organic cilantro.

Materials and Methods

Materials

Organic cilantro was harvested from Mae Poon Lung District, the Royal Project Foundation, Chiang Mai Province, in polyethylene bags, size 8”×12”. The vacuum cooling system used in this experiment included vacuum chamber, vacuum pumping system, condenser, refrigerator, and automatic control and operation system. The details of the vacuum cooling system are presented in Fig 1. The system was built by Hussmann Co., Ltd. (USA).

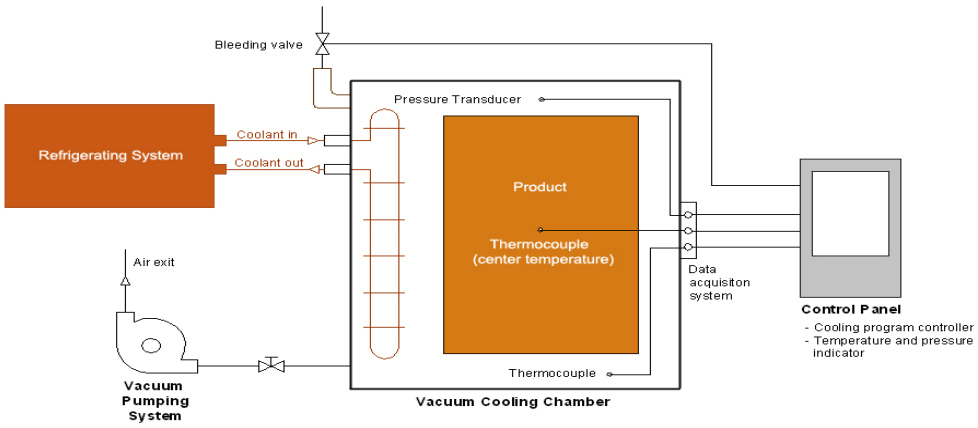

Figure 1. Schematic diagram of the research vacuum cooler.

Methods

Experiment 1: Study on optimum process parameters for vacuum cooling of organic cilantro.

Organic cilantro were graded, trimmed off defects and undesirable parts, then weighed 50 grams of graded organic cilantro and spread in the packaging. The packaging used in the experiment was a polyethylene bag sized 8"x12". Each plastic bag had 18 holes for plant transpiration. Subsequently, organic cilantro bags were placed in 60 baskets (500 grams/basket) then baskets were arranged in the vacuum chamber. The initial weight and temperatures of organic cilantro were measured and recorded, then all baskets placed inside the cooling chamber. The holding pressures for vacuum cooled cilantro were set at two different levels; 6 and 7 millibars and at the 3 levels of the vacuum pressure reserving; 1, 2 and 3 minutes, respectively for each level of pressure. Every 1 minute from the beginning through the end of the cooling process were recorded chamber pressure, temperature, relative humidity percentage and produce centre temperature. After immediate removing the samples from the cooling chamber, organic cilantro were weighed and recorded. Energy consumption of vacuum cooling process was measured and electrical expense in Thai baht was calculated.

Experiment 2: Study on the effect of vacuum cooling on physico-chemical properties of cooled organic cilantro.

This study was conducted on physico-chemical qualities of organic cilantro vacuum-cooled at the best condition from the first experiment using holding pressure of 6 millibars and with holding time of 1 and 2 minutes. The herbs were graded, trimmed off defects, undesirable parts and packed in polyethylene bags, then pre-cooled using the vacuum cooling system and stored until the end of its storage life at 5°C. Physico-chemical properties were analyzed everyday as follows: weight loss percentage, colour, expressed in L* value (L*), chroma (C*) and hue angle (h°) using a colourimeter (Chromameter, Minolta CR-310), ascorbic acid content [8], chlorophyll a, b and total chlorophyll [9], total soluble solids, using digital refractometer (PR-101, ATAGO) and shelf life was also analyzed [10].

Results and Discussion

Experiment 1: Study on optimum process parameters for vacuum cooling of organic cilantro.

In cooling organic cilantro to 5 ± 1°C, several sets of parameters were investigated. The optimum process parameters for vacuum cooled organic cilantro are displayed in Table 1. For other process parameters experimented, it was not possible to cool organic cilantro down to 5 ± 1°C (data not shown). Therefore the best process parameter was determines at 6 milibars.

Table 1. Optimum process parameters for organic cilantro vacuum cooled and measuring indices of vacuum cooling processes.

Process Parameters/Measuring Indices	Vacuum-cooled organic cilantro		
Holding pressure (mbar)	6	6	6
Holding time (min)	1	2	3
Cycle time (min)	12	13	14
Initial core temperature of herb (°C)	22-26	22-26	22-26
Final core temperature of herb (°C)	4-6	4-6	4-6
Weight loss (%)	0.67	0.81	1.33
Energy consumption (kWh)	0.09	0.10	0.12
Electrical Expense (baht/kg)	0.0094	0.0104	0.0128

The experimental results showed that the optimum conditions for vacuum cooling of organic cilantro was with an initial temperature of 22-26°C, pre-cooled with the best parameters obtained for the holding pressure at 6 mbar, the holding time of 1, 2 and 3 min, respectively. The total cycle time for the holding time of 1, 2 and 3 min were 12, 13 and 14 min. In terms of weight loss percentage for the holding times of 1, 2 and 3 min were; 0.67, 0.81 and 1.33%. Economic analysis showed that the vacuum cooling had an additional cost of 0.0094, 0.0104 and 0.0128 baht/kg, respectively.

The mechanism of temperature in the vacuum chamber during vacuum cooling can be expressed as follows: At first, the total pressure in the vacuum chamber is the sum of the partial pressure of air and water vapour. During vacuum cooling, the air is evacuated by vacuum pump, water vapour condenses into water in the vapour-condenser. The total pressure in the vacuum chamber is reduced from atmosphere to the set holding pressure. With the reduction of pressure in the vacuum chamber, the time at the beginning of boiling was determined, which is called the "flash point".

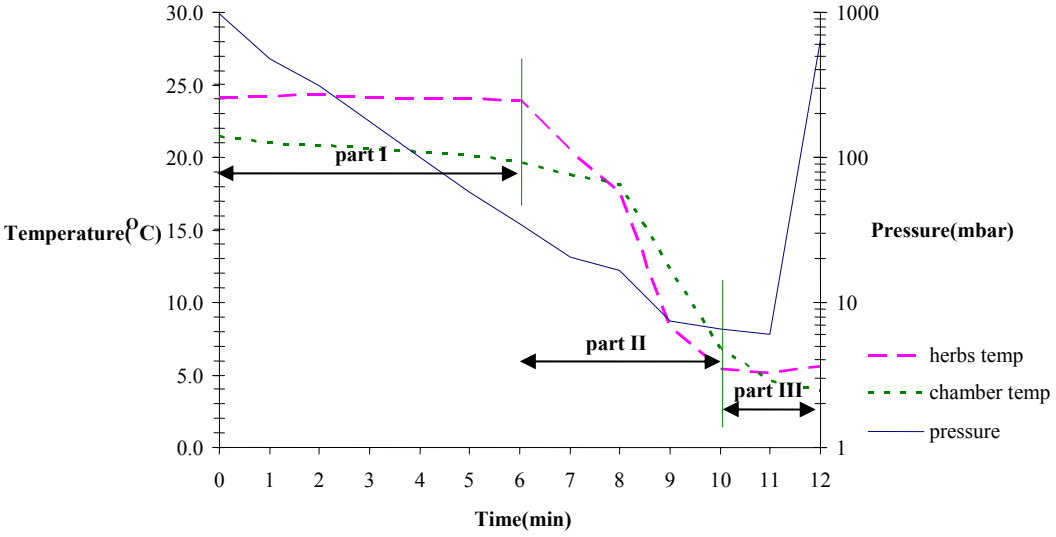

Figure 2. Temperature, pressure line in the vacuum chamber and cooling curve of organic cilantro during vacuum cooling at 6 mbar with 1 minute holding time.

The variation of product temperature can be divided as three different parts: part I, part II and part III as shown in Fig. 2. The temperature of organic cilantro slightly increased from 24.1 to 24.3°C during the first part (Part I). It can be explained by the fact that when pressure in the chamber decreases, the water in the herbs accumulates energy for transfer state from liquid to vapour, which can in turn increase the temperature of herb. Relative humidity in the chamber decreased when pressure dropped. In part II, the flash point was reached at the pressure in the vacuum chamber of 34.6 mbar. At this point, the rapid evaporation of water in the herbs started, at which the pressure in the vacuum chamber fell down due to saturation, which corresponded to temperature of the produce (23.9°C), consequently the herb temperature abruptly decreased after 6 minutes. Subsequently, most of the vapour was condensed in the vapour-condenser. After the first 8 minutes, the chamber temperature showed abrupt change at the pressure of 16.5 mbar, since the refrigeration unit of the cooling system started working. Together with the reduction of the vacuum pressure in the vacuum chamber and the temperature of chamber, the temperature of the herbs decreased from 24.3 to 5.4°C. The pressure in the vacuum chamber dropped from 970 to 6.0 mbar rapidly, reaching the reserving pressure of 6.0 mbar and holding it for 1 minute and the temperature in the vacuum chamber decreased from 5.4 to 5.1°C (part III). However, after 11 min, when the bleeding air valve was switched on, air at room temperature entering into the vacuum chamber caused an increase in the temperature of the herbs, with the final temperature being 5.6 °C. Weight loss occurs during vacuum cooling since the chamber cooling effect directly comes from water evaporation from the herb. Weight losses of organic cilantro during vacuum cooling for two different holding pressures are shown in Table 1. Weight loss percentage depends on the holding time. For the same holding pressure, the lower time that was used, the lower weight loss was experienced.

Experiment 2: Study of the effect of vacuum cooling on physico-chemical properties of cooled organic cilantro.

This experiment investigated the effect of vacuum cooling on the physico-chemical properties of organic cilantro stored at 5°C. The results showed that vacuum cooling had no effect on the loss of fresh weight, the change of colour (Table 2), total soluble solids (Table 4) and chlorophyll a, b, and total chlorophyll (Table 3) in organic cilantro, but had an effect on the amount of vitamin C (Table 4) and vacuum cooling was an important factor in maintaining a longer shelf life (Table 5) than organic cilantro not vacuum-cooled. After 3 days storage, the effect of vacuum cooling between cooled organic cilantro with holding time 1, 2 min and non-vacuum cooled samples were compared. Weight loss percentage of organic cilantro continued to increase in all treatments throughout the storage period. The amounts of vitamin C deviated between 20.38 and 47.74 mg/100 g fresh weight and total soluble solids tended to increase with storage time. The chlorophyll a, b and total chlorophyll tended to decrease with storage time, which correlated with the decreasing green colour. Deterioration in quality of organic cilantro, which was a shelf life indicator, was attributable to 5% of yellowing area on the leaves and more than 10% of wilting and rot.

Table 2. Influence of vacuum cooling on physical properties (mean of ± S.E.) of organic cilantro stored at 5°C for 3 days.

Treatment	Weight Loss (%)	L value (L*)	chroma (C*)	hue angle (h°)
Control (non-precooled)	4.29±0.33 [ns]	39.68±1.27 [ns]	19.93±1.81 [ns]	132.4±0.87 [ns]
Precooling with 6mbar for 1 min.	3.49±0.51 [ns]	42.31±1.01 [ns]	20.60±0.66 [ns]	133.0±1.03 [ns]
Precooling with 6mbar for 2 min.	3.16±0.54 [ns]	40.21±0.76 [ns]	21.14±0.75 [ns]	131.3±0.50 [ns]

[ns] ns means non significant at 95% confidence interval (P>0.05)

Table 3. Influence of vacuum cooling on chlorophyll content (mean of ± S.E.) of organic cilantro stored at 5°C for 3 days.

Treatment	Chlorophyll A (mg/100 g)	Chlorophyll B (mg/100 g)	Total Chlorophyll (mg/100 g)
Control (non-precooled)	0.2282±0.028 [ns]	0.0922±0.011 [ns]	0.3259±0.039 [ns]
Precooling with 6mbar for 1 min.	0.1939±0.014 [ns]	0.0791±0.005 [ns]	0.2778±0.020 [ns]
Precooling with 6mbar for 2 min.	0.2269±0.012 [ns]	0.0914±0.005 [ns]	0.3238±0.017 [ns]

[ns] ns means non significant at 95% confidence interval (P>0.05)

Table 4. Influence of vacuum cooling on total soluble solids and vitamin C (mean of ± S.E.) of organic cilantro stored at 5°C for 3 days.

Treatment	Total soluble solid (%)	Vitamin C (mg/100 g)
Control (non-precool)	8.5±0.10 [ns]	29.30±2.55 [a]
Precooling with 6mbar for 1 min.	8.8±0.90 [ns]	20.38±1.27 [b]
Precooling with 6mbar for 2 min.	6.8±0.40 [ns]	10.19±1.27 [c]

[ns] ns means non significant at 95% confidence interval (P>0.05)
Overall means with different letters in the last row are significantly different at 95% confidence interval (P≤0.05)

Table 5. Influence of vacuum cooling on shelf life (mean of ± S.E.) of organic cilantro stored at 5°C.

Treatment	Shelf life (days)
Control (non-precool)	3.2±0.20 [b]
Precooling with 6mbar for 1 min.	7.4±0.25 [a]
Precooling with 6mbar for 2 min.	6.8±0.20 [a]

Overall means with different letters in the last row are significantly different at 95% confidence interval (P≤0.05)

Conclusions

The optimum conditions for vacuum cooling process of organic cilantro were found to be with an initial temperature of 22 - 26°C pre-cooled with the best parameters obtained for the holding pressure at 6 mbar, the holding time of 1 and 2 min, respectively. In terms of weight loss percentage, the research also showed that herbs cooled with a holding time of 1 minute

had 0.67% weight loss, which is a small amount and less than cooled samples with holding time 2 minutes (0.81%). Weight loss percentage is closely related to the holding time. The vacuum cooling had no effect on the loss of fresh weight, the change of colour, total soluble solids and chlorophyll a, b, and total chlorophyll in organic cilantro but it did affect the amount of vitamin C. Vacuum cooling was found to be an important factor in maintaining longer shelf life than organic cilantro not vacuum-cooled. The research also exemplified the shelf life of organic cilantro pre-cooled to 5°C and stored at 5±1°C had storage time of 7 days and were significantly better preserved than organic cilantro not cooled (3 days).

Acknowledgements

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